

# WATER SURFACE TENSION FOR DIFFERENT TEMPERATURES

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# Introduction

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## Background Information

Understanding the science behind water surface tension is important. It helps us get our clothes clean, our glasses shiny and even makes our daily newspapers easier to read! When we know about surface tension we can predict how water will behave when we use it in lots of different situations.

Water is made up of molecules. The way these molecules stick together creates surface tension. It is a kind of invisible skin that holds water – and other liquids – together. When you want to use water it is sometimes important to break these molecules apart. For instance when you wash clothes you want the water to be able to flow freely so that the molecules can seep in and clean the clothes more efficiently. When you put detergent into a washing machine, it is there to break up the water surface tension. Hair shampoo also works by breaking up the surface tension holding the oil in your hair and letting it seep out. Skin cleansing products work the same way, using surfactants (substances which tend to reduce surface tension in liquids) to break up surface tension and let the oil out of your skin.

The printing industry is particularly concerned with surface tension because the ink that is squirted out of the cartridge and sticks onto the page needs to be a steady stream and not stick together. The more surface tension the ink has, the stickier it will be, this is because if the ink stuck together, the images that would be printed would come out in splotches and not as you see it on your own screen.

My experiment is concerned with how surface tension is influenced by one of the fundamental properties of water – its temperature. I want to understand if just changing the temperature can have an effect on how water will behave.

## Defining surface tension

Surface tension of water can be defined as ‘the cohesion of water molecules to each other is caused by the hydrogen bonding between the molecules. At the water's surface this interplay is asymmetrical and a rather unusual phenomenon occurs. It appears as though the liquid water has an invisible skin on it’ (All Science Fair Projects 2014). This phenomenon is illustrated in

Figure 1. This shows how each molecule exerts forces on the other molecules around it. Each arrow in the diagram represents which water molecule sticks to the other.

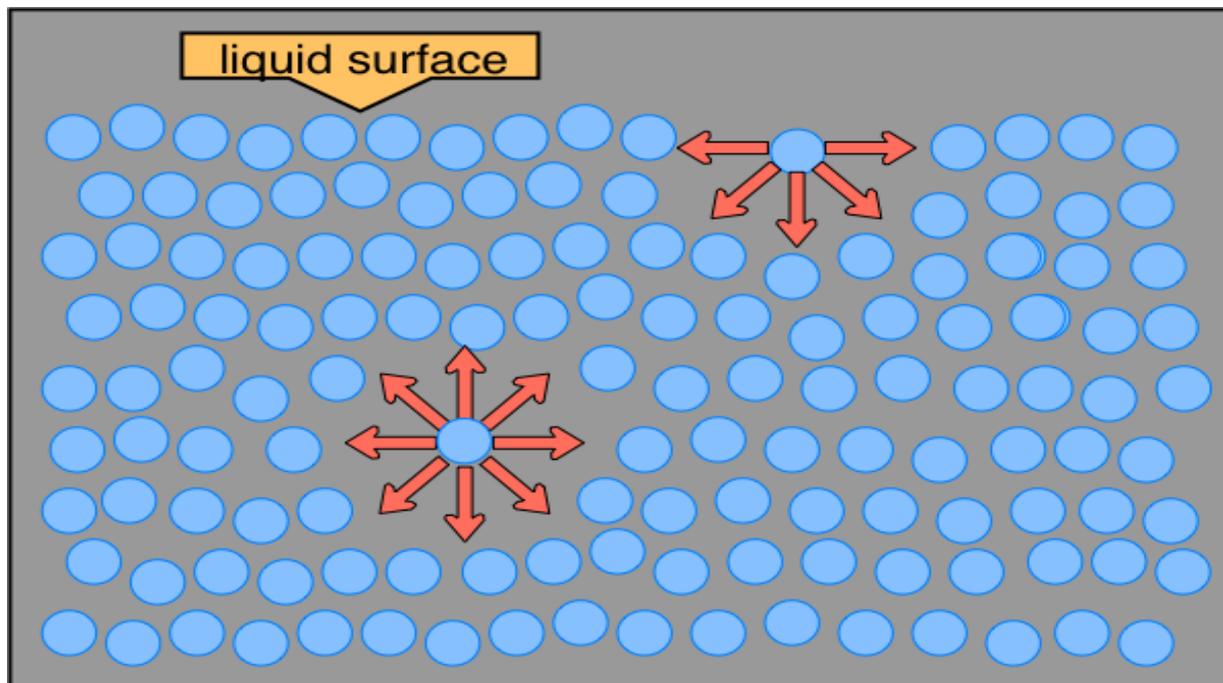


Figure 1, Diagram of how water surface tension works

This invisible "skin" on water can be visualized by floating sewing needles upon the surface. Of course; the metallic needle is several times denser than is water, such that if the needle is dropped onto the surface of water, it rapidly sinks to the bottom. But, using the most gentle of techniques, a needle of surprising size can be gently lowered onto the surface and it floats! Actually, this is not true floating - no more than you float in a waterbed. In the bed you lie atop a plastic membrane that acts as your "boat." The "floating" needle lies atop a film of tightly hydrogen bonded water molecules." (Science Projects 2013).

Another project carried out by a school student is this one; it was carried out as a science fair project in America. "Surface tension in water describes a condition where the surface of water that is in contact with air acts like a thin elastic sheet. It is a phenomenon that occurs on the surface of liquids when they are in contact with a gaseous medium. When there is contact between the surfaces of two liquids like water and oil, it is called interface tension. The molecules in a liquid (e.g. water) are drawn together by intermolecular forces known as Van der Waal forces. The molecules on the surface of the water are not surrounded by water molecules

on all sides. They will cohere more strongly with neighbouring water molecules, as opposed to air molecules. This creates a “film” on the surface which requires a certain amount of force to penetrate. The shape that is formed by a drop of water is caused by surface tension. Ideally all liquids will form a spherical shape in the absence of gravity in order to minimize their surface tension. This is because the sphere has the smallest surface area for a given volume. However, the shape of a water droplet is not spherical due to the force of gravity” (All Science Fair Projects 2014).

## Surface tension and temperature

Past research has shown that the surface tension of water can depend on some of the basic properties of the water such as its purity and its temperature. Although a lot has been written about the surface tension of water, the relationship between surface tension and temperature is still a matter of debate for many scientists. This is important if we want to know what the best temperature range for important processes involving water – such as printing.

Past research has shown that water surface tension and temperature have a linear relationship. As far back as 1894, Van der Waals gave a formula connecting surface tension and temperature.

**Van der Waal’s formula for the relationship between surface tension and temperature.**

$$\text{Surface tension} = Kpc^{2/3} Tc^{1/3} (1T/Tc)^n ,$$

Where T is the temperature, Tc and pc are the critical temperature and pressure, K is a constant, and n is a constant equal to approximately 1.23.

Van der Waal’s formula shows the mathematical relationship between surface tension and temperature. According to his formula, surface tension is directly related to temperature and pressure. In my tests, I have chosen to test the temperature side of this formula rather than trying to incorporate pressure into the test as well. Van der Waal’s formula implies that the surface tension of any liquid will become greater when the temperature of the liquid goes down below the average temperature of the room.

## Reason for choice of hypothesis

The work of Van der Waals and other scientists after him have established a relationship between surface tension and temperature. It draws on the fact that water molecules behave differently at different temperatures. My reasoning is that when water is cooled it freezes and becomes ice and a solid's surface tension is a lot greater than a liquid's. I thought that when water was colder, it was closer to being a solid so that it would result in having a greater amount of surface tension.

## Hypothesis

That when water temperature is below room temperature water surface tension is greater and when water's temperature is above room temperature water surface tension is lower.

## Aim

To compare water surface tension at different temperatures.

# Method and Materials

## Variables

**Independent variable:** The temperature of the water

**Dependent variable:** Surface tension

**Controlled Variables:** Room temperature, water depth, floating object, water salinity, water quality, air pressure

**Control Test:** Water from the tap left for ten minutes to achieve room temperature

## Materials Used

- 2x Piece of wood (325mm x 89mm x 19mm)
- Block of wood (135mm x 129mm x 40mm)
- 2x Nails
- 6x Screws
- Piece of wood (137mm x 24mm x 40mm)
- Cotton string
- Coat hanger
- Jug
- Rice
- Dowel
- Thermometer
- Rubber band
- Weight

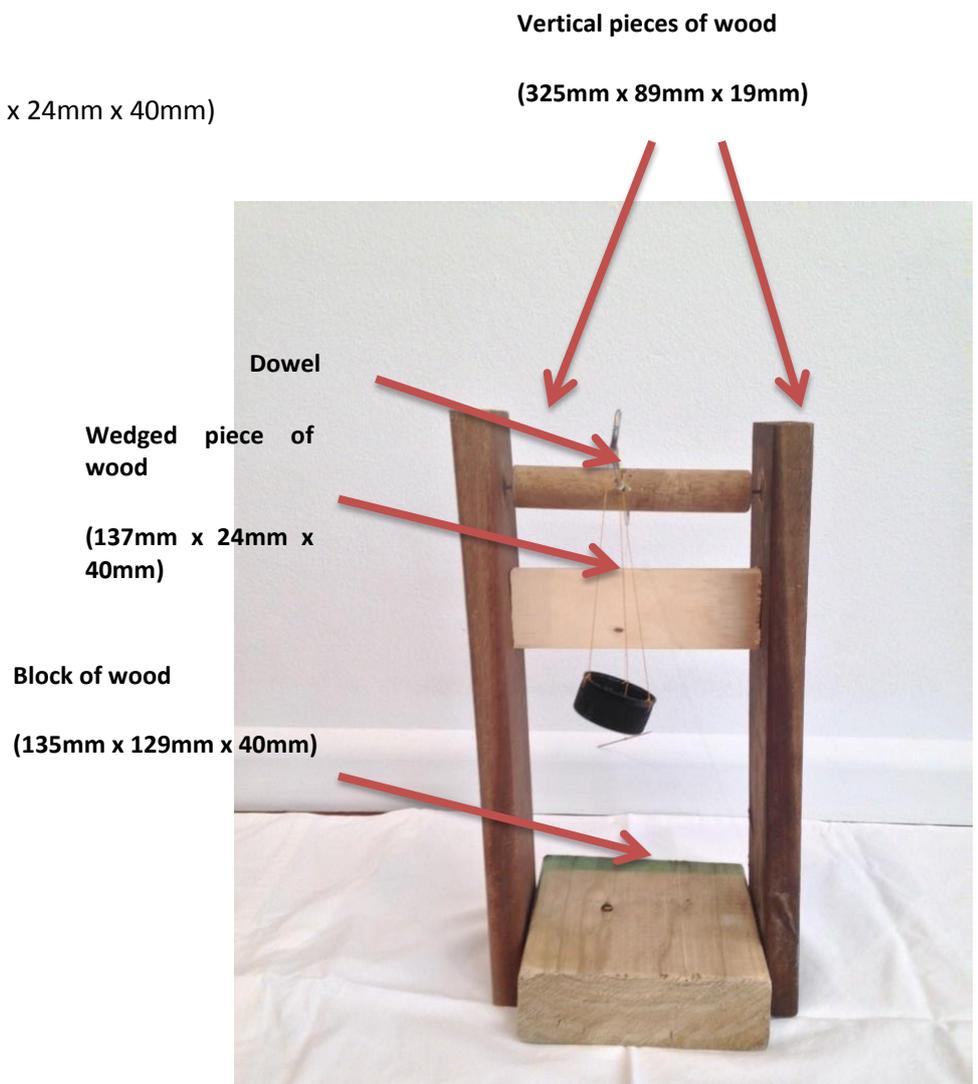


Figure 2 Front View of Final Experimental Apparatus

## Apparatus Construction

1. Materials were gathered
2. Two pieces of wood (325mm x 89mm x 19mm) were fixed to each side of another piece of wood (135mm x 129mm x 40mm) to create a square 'U' shape, holes were then drilled through the vertical pieces to make a pivot point for the nails
3. Nails were hammered into each side of the dowel to make the dowel pivot smoothly and then the nails on each end of the dowel were placed into the holes on the two vertical pieces of wood
4. A hole was then drilled through the dowel
5. The coat hanger was cut so that the straight piece of the coat hanger was by itself
6. The straight piece of coat hanger was slid through the hole in the dowel to act as the balancing beam

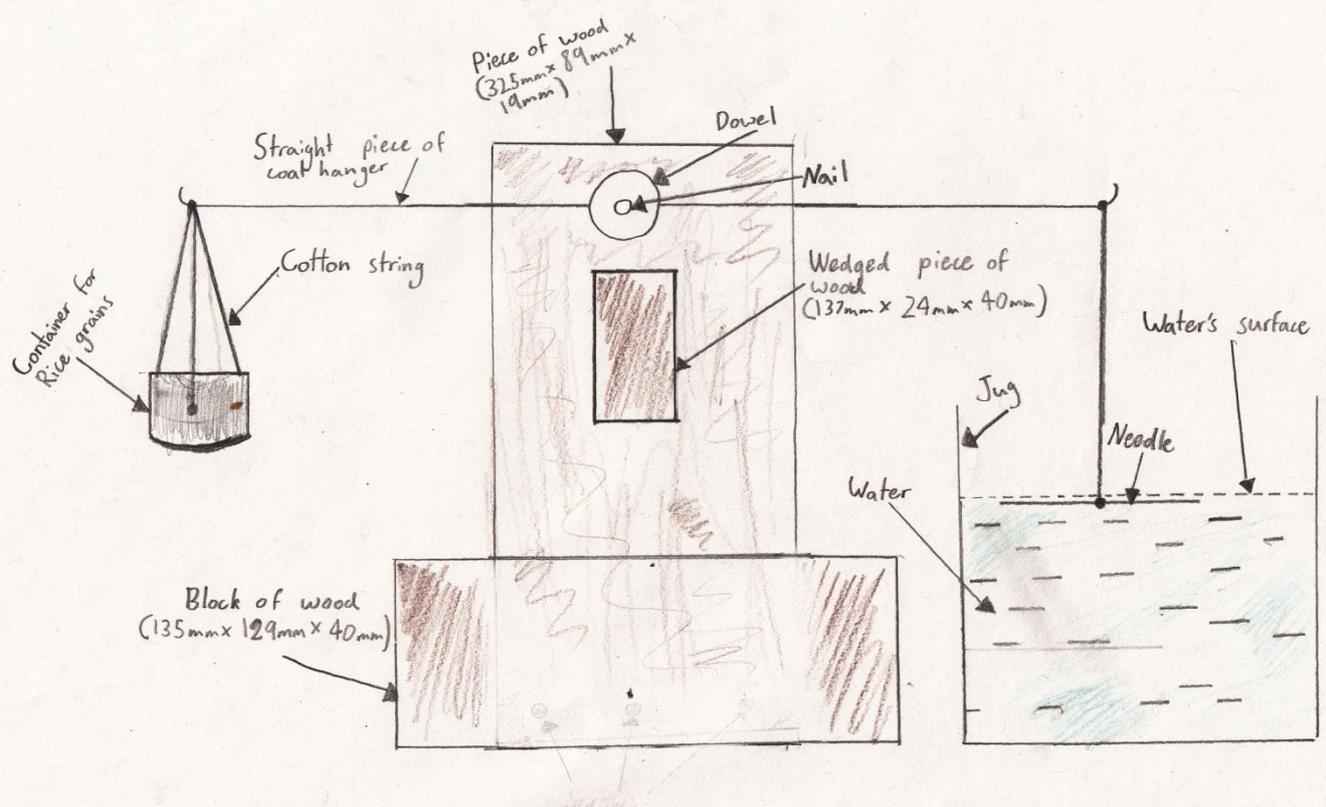
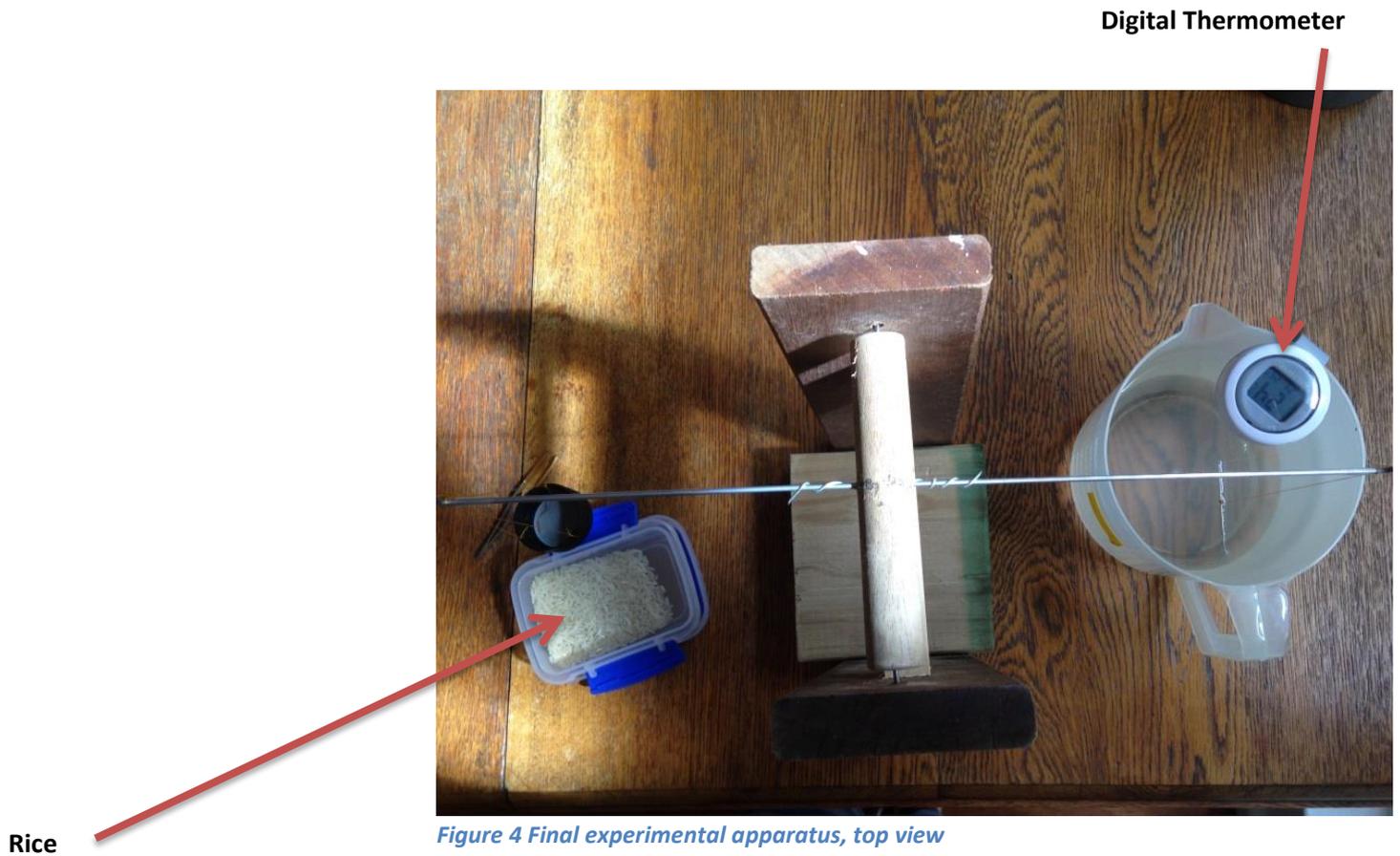


Figure 3 Diagram of a Cross-Sectional View of the Final Experimental Apparatus

7. Each end of the wire was bent upwards so that the needle and the bottle cap would not fall off
8. Cotton string was fixed to the bottle cap and the needle so that they were hanging parallel to the ground, then they were hung from each end of the wire
9. A piece of wood (137mm x 24mm x 40mm) was wedged in-between the two vertical pieces of wood to make sure that they were vertical and not tilted towards the center



*Figure 4 Final experimental apparatus, top view*

## Method Employed

1. Water was poured into the jug
2. The jug was placed underneath the hanging needle
3. The thermometer was weighted down and placed in the jug
4. The temperature of the water was noted and recorded
5. Grains of rice were placed into the bottle cap until the needle broke away from the surface tension of the water
6. The amount of rice grains needed to lift the needle out was then recorded
7. The experiment was repeated for temperatures around 25, 30, 35, 20 and 15, altogether 51 experiments were done

## Actions to improve reliability and validity

The methods used include a number of actions to improve the reliability and validity of my experiment.

The reliability of the experiment means that the method produces consistent and repeatable results.

Actions taken to improve reliability include:

- Multiple measurements at each temperature
- Standard procedures for each measure
- Use of a digital thermometer
- Use of control measures
- Completing a log book

The validity of the experiment means that it actually measures the variables in the hypothesis.

Actions taken to improve validity include:

- Investigating past research on the relationship between surface tension and temperature
- Using a recognized method for determining surface tension of water
- Keeping notes in my log book of external variables and issues that may affect the measurements.

# Results

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The table shows the test number, the temperature of the water and how many grains of rice were needed to pull the needle out of the water. For the room temperature water displayed at the top of the table I filled a jug with water from the kitchen tap and then left it for 10 minutes to achieve room temperature. After the measurements for room temperature were completed I removed a third of the water and replaced it with the same amount of hot/cold water depending on what test I was going to do. This was repeated again except that I removed two thirds of the water and replaced the same amount with hot/cold water depending on what test I was going to do.

The tables below detail all the results of all the temperature tests. These results are then summarised in Figure 5 which graphs each measurement the line of best fit (calculated using excel) shows the relationship between the number of grains of rice and temperature.

The line of best fit shows that when water temperature is lower than room temperature, the amount of weight needed to break the surface tension increases. The results of my experiment showed that there is a relationship between water surface tension and temperature. This is consistent with Van der Waal's formulae.

**Table 1: Room temperature tests** (1 grain of rice weighs 0.015625 grams)

| Test Number | Temperature (°C) | Grains of Rice |
|-------------|------------------|----------------|
| 1           | 25               | 30             |
| 2           | 25               | 30             |
| 3           | 25               | 30             |
| 4           | 25               | 26             |
| 5           | 25               | 26             |
| 6           | 25               | 27             |
| 7           | 25               | 28             |
| 8           | 25               | 25             |
| 9           | 26               | 30             |
| 10          | 27               | 31             |
| 11          | 26               | 31             |

**Table 2: Tests at around 15°C**

| Test Number | Temperature (°C) | Grains of Rice |
|-------------|------------------|----------------|
| 12          | 16               | 39             |
| 13          | 16               | 34             |
| 14          | 15               | 42             |
| 15          | 14               | 38             |
| 16          | 13               | 50             |
| 17          | 13               | 47             |
| 18          | 13               | 40             |
| 19          | 13               | 48             |

**Table 3: Tests at around 40°C**

| Test Number | Temperature (°C) | Grains of Rice |
|-------------|------------------|----------------|
| 20          | 38               | 26             |
| 21          | 40               | 24             |
| 22          | 41               | 27             |
| 23          | 42               | 25             |
| 24          | 42               | 23             |
| 25          | 41               | 24             |
| 26          | 41               | 26             |
| 27          | 41               | 22             |

**Table 4: Tests at around 35°C**

| Test Number | Temperature (°C) | Grains of Rice |
|-------------|------------------|----------------|
| 28          | 35               | 28             |
| 29          | 35               | 29             |
| 30          | 35               | 28             |
| 31          | 34               | 27             |
| 32          | 34               | 29             |
| 33          | 34               | 27             |
| 34          | 34               | 28             |
| 35          | 34               | 29             |

**Table 5: Tests at around 20°C**

| Test Number | Temperature (°C) | Grains of Rice |
|-------------|------------------|----------------|
| 36          | 21               | 35             |
| 37          | 21               | 40             |
| 38          | 21               | 38             |
| 39          | 21               | 39             |
| 40          | 21               | 42             |
| 41          | 21               | 40             |
| 42          | 20               | 41             |
| 43          | 20               | 39             |

**Table 6: Tests at around 30°C**

| Test Number | Temperature (°C) | Grains of Rice |
|-------------|------------------|----------------|
| 44          | 29               | 30             |
| 45          | 33               | 29             |
| 46          | 31               | 25             |
| 47          | 30               | 31             |
| 48          | 28               | 29             |
| 49          | 28               | 27             |
| 50          | 28               | 28             |
| 51          | 28               | 26             |

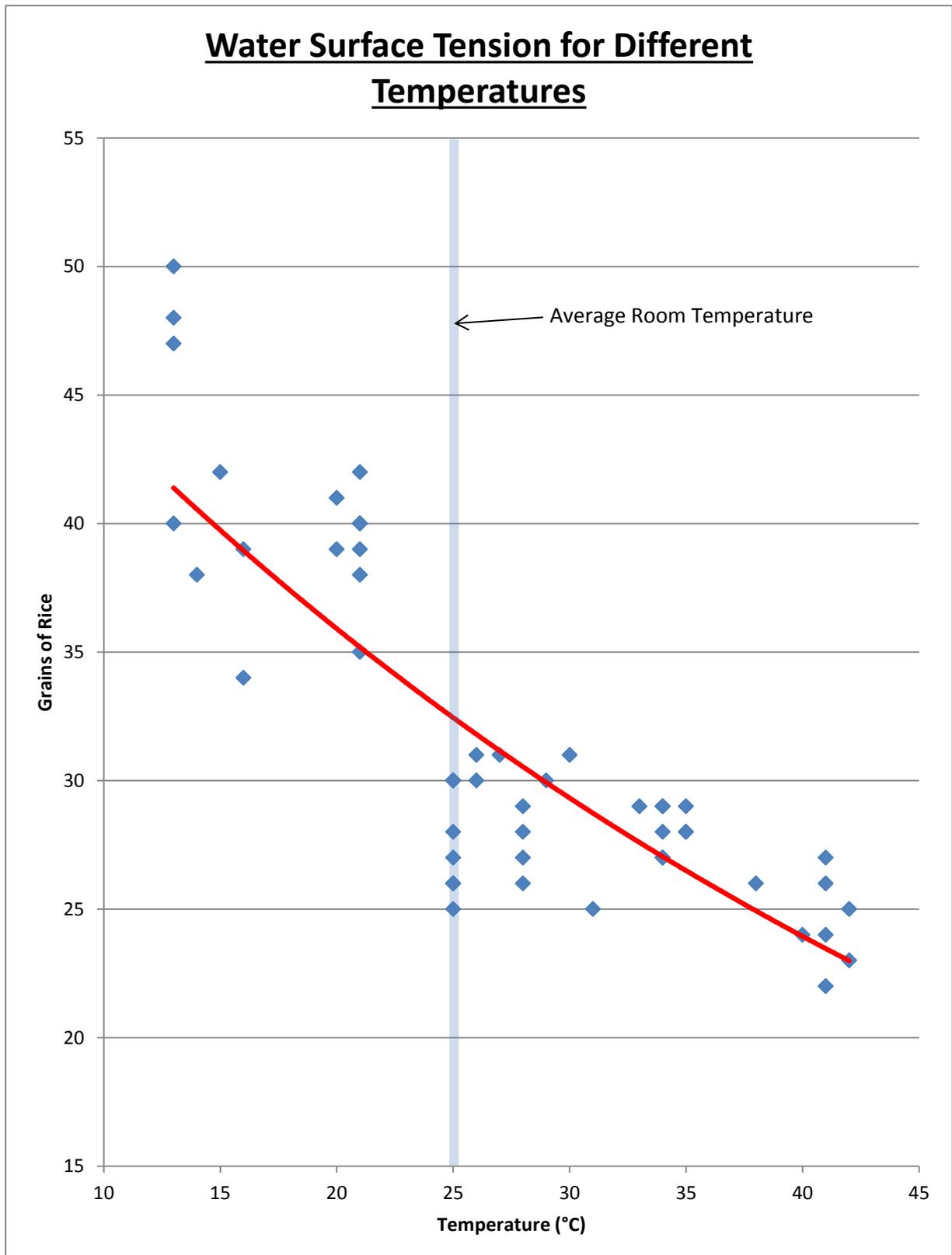


Figure 5 Graph of all results with each point representing each experiment

# Discussion

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## Discussion of Errors

To minimize the risk of errors each temperature was tested eight times. This was done to account for the water changing temperature towards the temperature of the room. I also performed 51 different experiments to make sure that my results really showed that there was a trend that when the temperature of water got colder and the amount of rice grains needed to pull the needle out of the water increased.

The experimental control for my experiment was that the water from the kitchen tap was left for ten minutes to achieve room temperature. This test was performed so that there was a benchmark temperature and starting point for my research. One problem that was outlined during class was that the water could act differently if the water's temperature history was different. For example the water was taken straight out of the tap and left, whereas the water that had its temperature changed had experienced being room temperature and was then heated up.

One key area of concern was the temperature sensor on the digital thermometer that was bought to help conduct the experiment. The sensor was revealed to operate at the top of the thermometer and not at the bottom as previously thought. This eliminated the previous experiments because the temperature measures had been incorrect because the digital thermometer was testing the temperature of the air above the water and not the actual temperature of the water. This was fixed by weighing the thermometer down by strapping a weight to the handle of the thermometer previously used to hang the thermometer on the side of the jug.

Another key area of concern was that each grain of rice could potentially be different sizes. The difference was only a couple of millimeters but this can make a huge difference. This is because the surface tension of water is not very strong and it takes on average 30/64 of a gram to pull a needle out of the water. Although this is a minute difference it can mean the difference to making the results go one way or the other. For example, if all the rice grains used for one of the tests were missing one half of them, each half a grain would be counted as one grain and the amount of grains needed to lift the needle out would double and give an incorrect result.

Another area of concern was that the digital thermometer did not show any decimal measures of temperature. The fact that I used a digital thermometer was so that I could accurately read the temperature without any human measurement errors. But the downside of this was that I could not see the difference in temperature down to one or two decimal places. I do not think that this problem affected my results greatly because the surface tension could not change in a measureable way in the difference of 0.1-9°C. This was an error with my experiment but it would not have changed most of my results even if I could see down to one or two decimal places.

## Improvements

An area of improvement that could have been made in my experiment was the control test. The control could have improved by heating the water up and then cooling it down, then letting it come back to room temperature. This improvement would be performed because after the heating and cooling, the room temperature water would have had the same temperature history as the other water samples. This would have eliminated the possibility that what changed the water surface tension was only partly the actual temperature of the water, but mostly what the water had experienced. The surface tension could change if the molecules had been moving very fast and very slowly then going to moving at normal speed, this could have affected my results greatly.

The final area of improvement that I could have integrated into my experiment was to have a thermometer that could read the temperature down to one or two decimal places. As I have stated earlier, this would have made a minor difference to my results because the surface tension would change by an immeasurable amount in the space of 0.1-0.9°C.

## Conclusion

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Following the results in my experiments I have been led to conclude that my hypothesis is confirmed 'That when water temperature is below room temperature water surface tension is greater and when water's temperature is above room temperature water surface tension is lower'. This is because my tests had shown that when the temperature of the water had been cooler than room temperature, the amount of grains needed to raise the needle out of the water's grasp increased. Therefore the industries that would benefit from my results would need to examine my data and either heat up or cool down the liquid that they are using to achieve their products' aim respectively.

This topic requires further testing with more accurate measuring equipment and a larger amount of temperature samples to further investigate the difference of surface tension.

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